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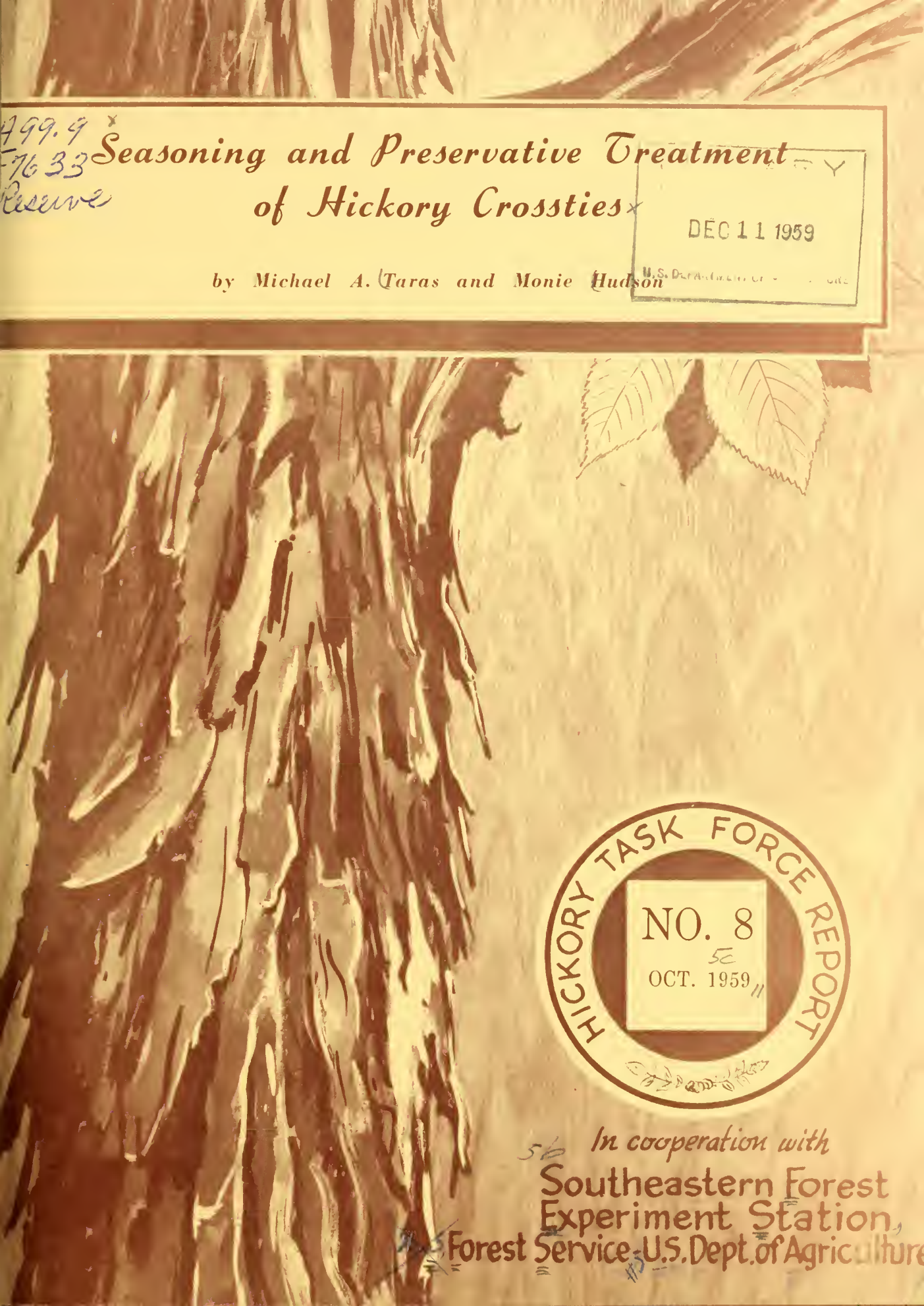
Seasoning and Preservative Treatment of Hickory Crossties

DEC 11 1959
U.S. Department of Agriculture

by Michael A. Taras and Monie Hudson



HICKORY TASK FORCE REPORT

NO. 8

OCT. 1959

In cooperation with
Southeastern Forest Experiment Station,
Forest Service-U.S. Dept. of Agriculture

FOREWORD

Hickory (Carya spp.) has earned the reputation of being one of the world's toughest woods. In shock resistance it has no equal. The reputation earned by hickory is based on the performance of high quality material in products requiring a high degree of strength and toughness.

Today, a limited quantity of high-grade hickory is available and its value and scarcity are well recognized by the wood-using industries. There is, however, a large volume of low-grade hickory that was bypassed when loggers cut our hardwood forests, and many land managers are troubled by the increasing amount of growing space occupied by it. Although this low-grade hickory does not possess the quality or properties required in many products, it is a potentially valuable wood for many uses.

A conference of federal, state, university, and industrial representatives was held in Clemson, S. C., in April 1953, and the Hickory Task Force was organized to promote the utilization of hickory. Accomplishment of this objective will be reached through research and publication of known information.

The Southeastern Forest Experiment Station has assumed the responsibility to edit, publish, and distribute reports containing information which will be developed under this program.

Full acknowledgment is due the many cooperating agencies and individuals who are making the project possible. Subject Matter Committee Chairmen are:

John Drow, Forest Products Laboratory, Madison, Wis., Growth and Properties of Hickory.
Roger Anderson, Duke University, Durham, N. C., Enemies of Hickory.
Roy M. Carter, N. C. State College, Raleigh, N. C., Manufacturing and Seasoning of Hickory.
John W. Lehman, Tennessee Valley Authority, Norris, Tenn., Products from Hickory.
Lenthall Wyman, N. C. State College, Raleigh, N. C., Hickory for Fuel.
C. E. Libby, N. C. State College, Raleigh, N.C., Hickory for Fiber.
Monie S. Hudson, Spartanburg, S. C., Treating Hickory.
Richard D. Lane, Northeastern Forest Experiment Station, Upper Darby, Penna., Marketing of Hickory.

Walton R. Smith, Chairman
Hickory Task Force. Report no. 8/11

See the inside back cover for a list of hickory reports planned.

SEASONING AND PRESERVATIVE TREATMENT OF HICKORY CROSSTIES

by

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INTRODUCTION

About fifty years ago, the annual consumption of hickory (Carya spp.) amounted to nearly 400 million board feet. The many changes in our way of life over the past fifty years have brought about a considerable decline in the use of hickory, and the annual consumption of hickory today is in the neighborhood of 150 million board feet, including fuel. The quality hickory cut today is used primarily by the striking tool handle industry, the sporting goods industry, and the picker stick industry. There are, however, millions of board feet of hickory in our forests today which can be used for products with less exacting requirements. Crossties are among these products and could serve as an excellent outlet for millions of feet of hickory annually.

Hickory is the strongest of the hardwoods used for crossties, yet very little hickory is used for this purpose. The shock resistance of hickory is over twice that of white oak, one of the more desirable crosstie species. If the composite strength (including bending strength, hardness, compressive strength) of white oak is given a value of 100, the composite strength for hickory is about 130. At this point the question arises: why isn't hickory used more for crossties? There are two reasons which were disclosed by a survey of the railroads made by Hudson (8) in 1952. Seventy railway companies in the eastern part of the United States were contacted and 39 responded. Of these, 30 did not use hickory for the following reasons:

1. Excessive checking and splitting and tendency to decay or become infested with insects during seasoning.

2. Regarded as a difficult species to treat properly.

Of the other 9 railroads that responded in the survey, all accepted hickory, ranging from a maximum of 5 percent of their tie purchases to no set limit. The total number of ties used by these 9 roads in 1952 was slightly over 5 million (about 20 percent were hickory).

After discovering the reasons why hickory was not being used by the railroads, the Wood Preservation Committee of the Hickory Task Force encouraged and promoted research in the seasoning and treatability of hickory crossties. This report is a compilation of the work done over the past six years by various railroads, wood preserving companies, schools, and other public agencies in an effort to eliminate or correct the objectionable features of hickory which have influenced its acceptance by all railroads. An effort was made in this report to include the results of numerous studies conducted on hickory crossties. In some instances, available data are too meager to judge the adequacy of preservative treatment, but the results are of interest in the over-all appraisal of the problem.

Hudson (9) in 1958 estimated that about 2 million hickory ties per year were now used by the railroads. This is about 33 percent of the 6 million mixed hardwood ties reported being treated in 1957, and represents an increase of about a million hickory ties over the number used in 1952. According to Hudson, this growth in the use of hickory ties probably has increased the over-all consumption of hickory by about 40 percent.

SEASONING AND TREATABILITY

To be treated effectively, crossties must be seasoned to a moisture content somewhere between 20 and 40 percent. The lower the moisture content in this range, the better the treating results. In the past, air-seasoning was the only method used to dry crossties; however, in recent years other drying methods, such as controlled air-seasoning and vapor-drying have come into the crosstie seasoning picture. Kiln-drying, which in the past was considered a rather expensive and impractical process to dry crossties, is now also being considered and is under study.

Air-Drying

Air-drying is the simplest and most commonly used method of drying crossties. The same principles and drying practices used in drying hickory lumber (14) should also be used when air-drying crossties, if uniform and rapid drying without excessive seasoning defects is expected. The seasoning yard should be located on an elevated, well drained site, and kept free of debris, weeds, and other obstructions which would hinder airflow. Foundations should be built of sturdy treated timbers or some other durable material, such as concrete piers, blocks, or steel so that the first course of ties is 18 to 24 inches above the ground. Piling practices commonly used are the 1 x 9 and 2 x 9 methods (fig. 1). Note that in the 2 x 9 piling the end ties are turned on edge, thus reducing the area of contact of the other ties in the tier. Both methods of piling afford good air circulation through the pile and minimum contact area between ties. Rate of drying may be controlled to some extent

Figure 1.--Piling methods used in air-seasoning crossties. Left, 1 x 9 method. Right, 2 x 9 method. (Photo by Taylor-Colquitt Co.)

by varying the spacing between ties as well as between the piles. The time required to air-dry crossties is dependent upon such factors as species of wood, moisture content, proportion of sapwood to heartwood, climatic conditions, season of the year, and locality. These factors make it difficult to predict or set an established air-drying time that would hold true for the entire geographical range of hickory. Table 1, adapted from Henderson (5), shows the time needed to air-dry different species of wood in various parts of the country to a moisture content suitable to preservative treatment.

The Railway Tie Association Subcommittee Number 1 on Stacking Methods (1) reports that hickory may be dried to a moisture content of 20 to 30 percent in 6 to 8 months, depending upon the location of the plant. However, detailed information on the air-drying rate of hickory in various parts of its range is rather limited.

In 1954 Hudson (8) reported that Plastre of the Atlantic Coast Line air-dried 186 nine-foot hickory ties in Gainesville, Florida. Using the 1 x 9 stacking method, one group of 93 ties was seasoned for 3 months and another group of equal number for 6 months. Following the respective drying periods, observations were made on the extent of splitting which took place because of drying (table 2).

It is apparent from these data that 3 months seasoning is inadequate to reduce the moisture content to a level suitable for treating (20-40 percent moisture content), and that at least 6 months seasoning is necessary.

Table 1. --Approximate air-seasoning periods for railway ties considered sufficient for preservative treatment

Species	Region	Method of piling	Seasoning time	
			Piled in early spring or summer	Piled in winter or fall
			Months	Months
Ash	Lake and Northeastern States	1 by 9	7	10
Beech	Lake and Northeastern States	1 by 9	4	12
Birch, Y.	Lake and Northeastern States	1 by 9	4	8
Cherry	Lake and Northeastern States	1 by 9	4	8
Chestnut	South Atlantic	1 by 9	3	8
Elm	Northern	1 by 9	6	9
Gum	Southern	1 by 9	3	6
HICKORY	Central	1 by 9	8	13
Locust	Central	1 by 9	8	12
Maple	Northern	1 by 9	4	8
Oak, R.	Lakes States	1 by 9	8	12
Oak, W.	Lakes States	1 by 9	10	18
Sycamore	Central	1 by 9	6	9
Douglas fir	West Coast	1 by 9	3	6
Douglas fir	Rocky Mountains	1 by 9	1	6
Hemlock	Eastern and Western	1 by 9	3	12
Loblolly pine	Southeastern	1 by 9	2	5
Shortleaf pine	Southeastern	1 by 9	$2\frac{1}{2}$	6
Longleaf pine	Southern	1 by 9	4	8
Lodgepole	Rocky Mountains	1 by 9	4	8
Ponderosa pine	Rocky Mountains	1 by 9	4	6
Larch	Eastern and Western	1 by 9	4	12

Table 2. --Results of air-drying study of hickory crossties by the Atlantic Coast Line Railroad (8)

Group	Air-drying period	Time of year	Moisture content		Ties with end splits 1/	Ties splitting
			Initial	Final		
	Months		Percent	Percent	Number	Percent
1	3	January to April	57.5	42.3	8	8.6
2	6	January to July	59.5	34.3	39	41.9

1/ Splits--any continuous opening from 1 face of the tie to the other into which a pencil (about $\frac{1}{4}$ inch) could be inserted at the widest point.

Both groups of ties air-seasoned by Plastre were treated with an 80/20 solution of creosote and fuel oil under the same impregnation schedule, that is: 50 p. s. i. initial air pressure and 175 p. s. i. preservative pressure at 200° to 210° F. for 4 hours and 45 minutes. Group 1, seasoned for 3 months, had an average moisture content of 42.3 percent and retained 4.6 pounds per cubic foot of preservative which penetrated to a depth of 1.4 inches. About 64 percent of the sapwood was treated in this group. Group 2, air-seasoned for 6

months, had an average moisture content of 34.3 percent and retained 4.8 pounds per cubic foot of preservative which penetrated, on the average, about 1 inch into the wood. In group 2 about 73 percent of the sapwood was penetrated. Although some improvement in sapwood penetration can be noted in the ties seasoned 6 months compared to those seasoned for 3 months, sapwood penetrations fell short of the A.W.P.A. Standard C6-54 requirement (95 percent sapwood penetration). The minimum retention requirement (8 lbs. per cu. ft.) under the Federal Specification TT-W-571 was not acquired in either group. The results of this experiment indicate that either longer periods of seasoning are necessary in order to reduce the moisture content further, or some modification in the treating, or both, are necessary if the treated air-dry hickory ties are to meet the specification requirements.

Shinn (15), in 1955, air-seasoned 626 freshly cut grade 4 and 5 hickory ties to determine the extent that incising would retard checking and splitting. These ties were air-dried in Orrville, Ohio. Five-inch C-irons were applied to each end of the ties immediately upon arrival at the seasoning yard. One-half (313) were incised and stacked by conventional yard methods (1 x 9 stacking, 15 ties high). These ties were cut during the winter months and air-dried from January 1954 to April 1955. Following this 15-month drying period, the incised ties had an average moisture content of 26.4 percent and the unincised ties 26.9 percent. A detailed examination of the ties showed that there was less checking and splitting of the incised ties in comparison to the unincised. The checking and splitting in the unincised ties was not as serious as expected; splitting in the incised ties was less than normally occurs in mixed oak. The degree of splitting which occurred, as determined on a sample of 47 incised ties and 45 unincised ties, is as follows:

Width of checks in end area	Incised ties (Number)	Unincised ties (Number)
Less than 1/8 inch	31	21
1/8 to 3/8 inch	11	21
More than 3/8 inch	5	3*
Total	47	45

* Checks in this category were more numerous and of larger dimensions than those found in the incised ties.

Because there are no standard specifications on size limitations of splits in seasoned crossties, each processor sets his own limitations on split sizes. An example of split specifications, mutually agreed upon by the Atlantic Coast Line Railroad and the Langdale Company, Valdosta, Georgia,[1/] is as follows:

> "If a tie is split 1/4 inch and extends into the tie 6 inches or more, the tie needs doweling. If the split occurs lengthwise along the tie to the point at which it enters the adzed face (approximately 14" from the end) and at this point is greater than 1/8 inch in width, the tie is rejected. If the split as measured across the end of the tie is 1-1/4 inches in width, the tie is rejected, regardless of whether the split is in a vertical or a horizontal plane."

1/ Correspondence with J. F. Hanahan, Vice-President, Wood Preserving Division, The Langdale Company, Valdosta, Georgia. 1959.

Although specifications will vary among processors, the above splits limitations should be kept in mind when other data involving splits and doweling are presented later in the text.

The 626 ties used in this air-seasoning study were treated by the Rueping process in two separate charges. A preliminary air pressure of 15 pounds was used on the unincised ties and 10 pounds on the incised ties. The preservative consisted of 50 percent heavy No. 6 fuel oil and 50 percent creosote with a residue of approximately 20 percent at temperatures above 355° F. The solution pressure was raised in one hour to 200 p.s.i. and maintained at this level for 3 hours and 40 minutes. The total amount of preservative pressed into the incised and unincised ties was 6.99 pounds per cubic foot and 5.64 pounds per cubic foot, respectively. Of these amounts, 57.7 percent and 48 percent, respectively, was pressed into the ties during the first half hour of treatment (before the pressure reached 125 p.s.i.). Average preservative retention after treatment was 6.01 pounds per cubic foot for the incised ties, compared to 5.25 pounds per cubic foot for the unincised ties. The average depth of penetration was 1.26 inches in the incised ties and 1.35 inches in the unincised ties. Although average penetration was lower in the incised ties, the preservative penetrated more uniformly. It was impossible to detect the depth of sapwood on all of the ties examined; however, where sapwood was detectable, there were no cases of preservative penetration into the heartwood. Of the 45 unincised ties examined, 15 had a penetration of 1/2 inch or less; only 8 ties of the 45 incised ties showed penetration at this low level.

Controlled Air-Seasoning (C.A.S.)

Controlled Air-Seasoning (C.A.S.) (16, 17) is a method of drying wood which was developed some years ago by the Southern Wood Preserving Company in an effort to reduce the drying time of green pine poles. Drying is accomplished in a long, narrow, well insulated building made of any materials that are economical from the standpoint of cost and maintenance. Design of the chamber is dependent upon the size of material to be handled, space available, handling equipment to be used, and desired capacity. It may be a long, straight chamber, or it may be in the form of a "U." The unit is equipped with a heat source and a fan which provides air circulation. Temperature and air circulation are regulated by automatic controls that function in response to the air volume and temperature requirements of the charge during the entire drying period. This process differs from kiln-drying in that considerably lower temperatures are used and the process dries material to a moisture content of approximately 20 percent. Vaughan[2/] experimented with 509 incised hickory ties using the Controlled Air-Seasoning method of drying. The ties which were used in the experiment had air-seasoned for 30 days prior to the C.A.S. drying, and had a green moisture content ranging from 45 percent to 61 percent.

2/ Vaughan, J. A. The use of hickory for railroad crossties. Southern Wood Preserving Company Report, File 11-A-5 HTS, 5 mimeographed pages. 1954.

After 11 days of drying in the C.A.S. unit, the moisture content of the ties ranged between 41 and 46 percent, and there were 85 ties that required doweling. The following tabulation shows the number of ties which were acceptable for use after Controlled Air-Seasoning:

Tie condition	Number of ties	Percent of total ties
Satisfactory	326	64.0
Satisfactory if doweled	85	16.7
Satisfactory with 6-inch face	58	11.4
Culls due to splitting	40	7.9
Total	509	100.0

The ties in this experiment were all treated in one charge with an 80/20 creosote and coal tar solution. Treating conditions used were as follows:

Treating condition	Treating time
Initial air pressure - 40 p. s. i.	25 minutes
Preservative pressure up to 200 p. s. i.	2 hours
Preservative pressure held at 200 p. s. i.	45 minutes
Vacuum up to 22-inches Hg.	20 minutes
Vacuum to 23-inches Hg.	1 hour
Filling and emptying cylinder	1 hour
Total treating time	5 hours: 30 minutes
Preservative temperature 177° to 210° F.	

Net retention of preservative was 6.02 pounds per cubic foot. Penetration determinations were made on a sample of 21 ties selected randomly from the charge. Increment cores extracted from the center of each tie disclosed the following penetration results:

Penetration (Inches)	Number of ties	Percent of ties
0.5 to 1.0	8	38
1.1 to 1.5	12	57
Over 1.5	1	5
Total	21	100

Average penetration for the group was 1.3 inches, and the preservative also appeared to be well distributed.

Vapor-Drying

Vapor-drying is an accelerated drying technique developed and patented by Monie Hudson (6). In this method of drying, conventional pressure-treating cylinders are used as drying units. After the wood is sealed in a cylinder, hot vapor of an organic seasoning agent with a boiling point range between 212° and 400° F. is introduced into the cylinder for the purpose of heating the charge. As the wood is heated by the vapor of the seasoning agent, water is vaporized from the wood into the cylinder atmosphere. Then, together with the seasoning agent vapor, the water vapor goes to a condensor where both are condensed to liquids. The water and seasoning

agent are separated by gravity because of the immiscibility of the two liquids. The water is drawn off and the seasoning agent returned to the heating tank where it is re-used. In a commercial treating unit, it takes about 30 minutes to reach stable operating conditions. After the drying period is completed, a vacuum is pulled on the charge to recover the solvent that penetrated the wood. Some moisture is also removed from the wood during the vacuum period. Drying time is dependent upon the green moisture content of the material, the size of the material, and the final moisture content desired. In the case of ties, drying time ranges between 12 and 16 hours.

Vapor-drying has been effective in reducing checking and splitting in oak crossties. In view of this, Hudson (7) vapor-dried several charges of ties from an upland hickory stand that had air-seasoned about one month. The ties were processed with 21 ties to a charge. The initial moisture content of the ties averaged about 53 percent. After 12 hours of vapor-drying, the moisture content of the ties was down to 35 percent. Results of this study showed the rate of vapor-drying for hickory to be almost identical to that of red oak. Because of the high temperature involved in drying, it was also concluded that the ties were completely sterilized. None of the hickory ties dried in this study showed evidence of excessive checking and splitting.

The ties in this experiment were given the same impregnation cycle used to treat vapor-dried red oak ties. The treatment resulted in a retention of 6.4 pounds per cubic foot of preservative with an average penetration of 1.7 inches. Minimum penetration was 0.4 inch and maximum 3.1 inches.

In 1953, Collister (4) of the Santa Fe made an exploratory study on 8 hickory ties using the vapor-drying method. The ties had a green moisture content of 73 percent. After 14 hours of vapor-drying, the final average moisture content was 42 percent. These ties were given a full cell treatment with a mixture of 30/70 creosote and petroleum. Final retention of the preservative was 11.77 pounds per cubic foot. Figure 2 shows the distribution and depth of penetration in 4 of these 8 ties. All ties were acceptable and without appreciable checking and splitting. These ties lay in the open for 15 months to observe their behavior after exposure to climatic conditions, and all were in excellent condition after the exposure period. In view of this, the experiment was repeated on thirty-five hundred hickory crossties 6 by 8 inches by 8 feet. The drying time for the four charges in this experiment and the moisture content before and after drying are given in table 3.

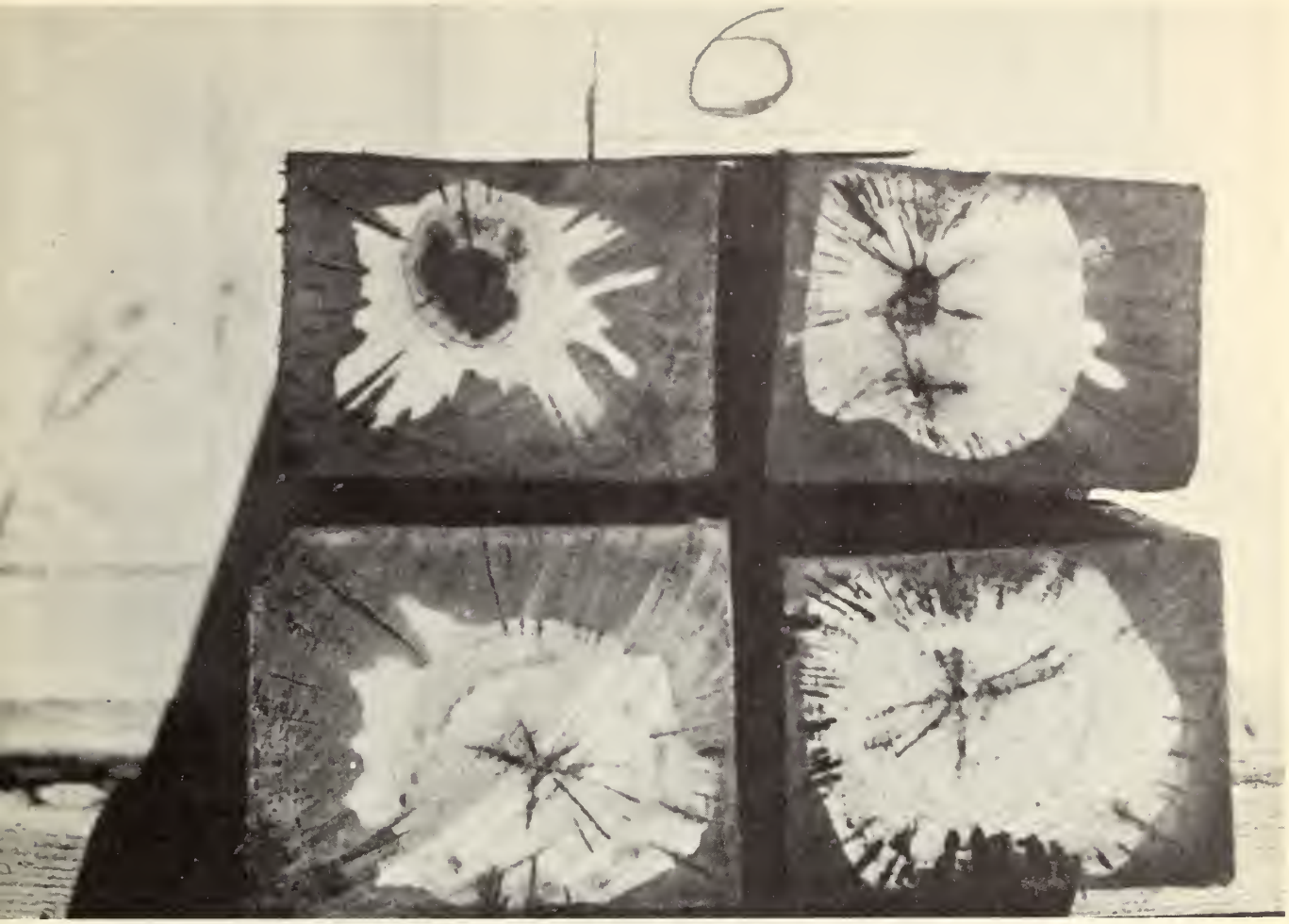

Figure 2.--Depth of penetration and preservative distribution of 4 vapor-dried ties treated with 11.77 pounds per cubic foot of preservative. (Photo by Santa Fe.)

Table 3. --Moisture content before and after drying and preservative retention and penetration in vapor-dried hickory crossties (4)

Charge number	Moisture content		Drying period	Preservative retention	Penetration		
	Green	Dry			Maximum	Minimum	Average
	Percent	Percent	Hours	Lbs./cu. ft.	Inches	Inches	Inches
1517 V	53.5	28.6	12	9.07	3.50	.06	1.59
1524 V	48.5	22.2	15	9.18	2.75	.50	1.53
1530 V	48.9	18.2	15	10.77	3.75	.25	2.18
1538 V	55.2	19.2	15	15.13	2.50	1.00	1.78

Of the thirty-five hundred ties dried in this experiment, 95 percent were acceptable for use and 5 percent required doweling in order to be acceptable. These ties were treated with a mixture of 30/70 creosote and petroleum oil under the following schedule:

Seasoning and treating cycle	Time (Hours)
Vapor-drying	15
Hot vacuum	2
Bringing pressure up to 175 p. s. i.	1
Pressure maintained at 175 p. s. i.	4
Final vacuum	1
Total time	23

The average penetration and retention for each charge is shown in table 3. Figure 3 shows typical penetration and preservative distribution in several ties taken from charges 1524-V and 1530-V. Figure 4 shows the condition of the ends of two sample tram loads of hickory crossties before drying and after drying and treating.

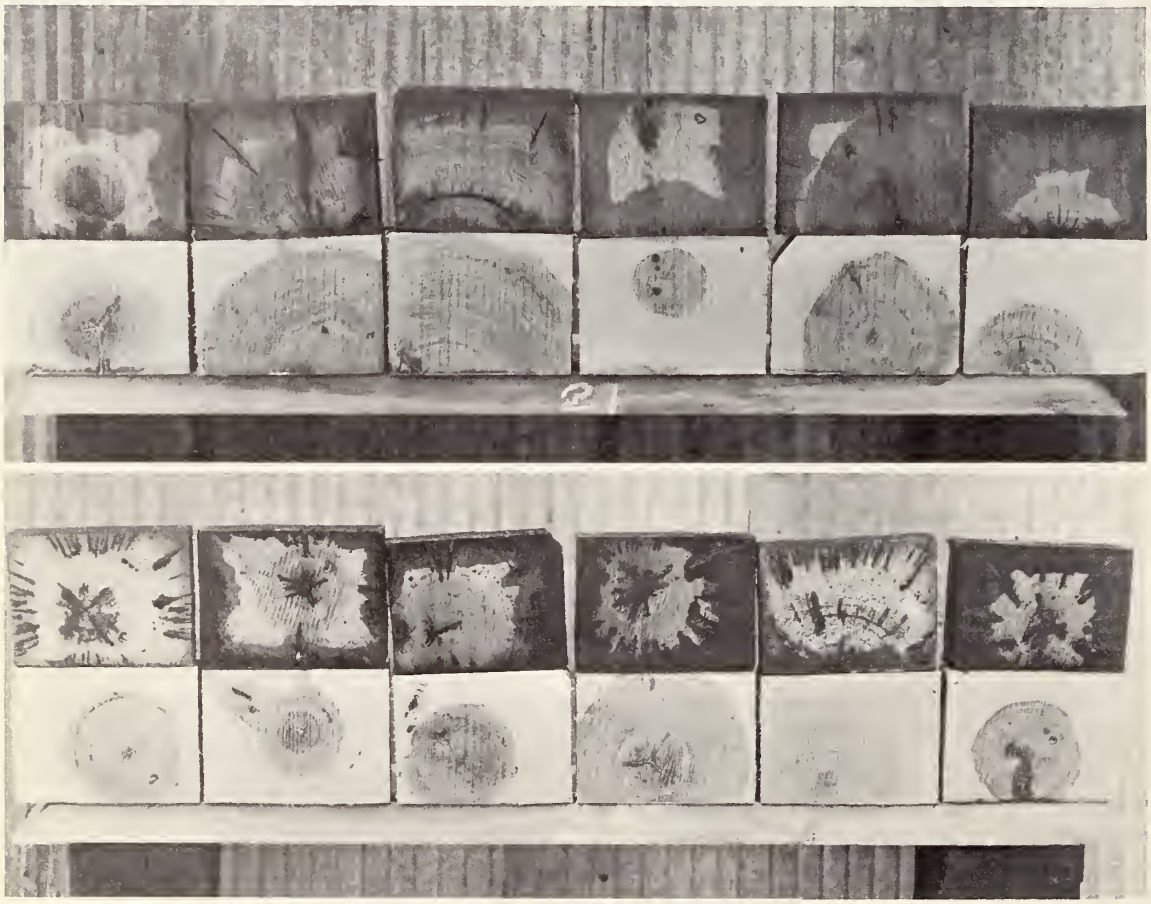

Figure 3.--Preservative penetration and distribution patterns in vapor-dried crossties treated by the Santa Fe with 30/70 creosote and petroleum. Above, Charge 1524-V. Below, Charge 1530-V. (Photo by Santa Fe.)

As a result of this research, the Santa Fe railway is now accepting hickory as a standard tie species. Blair (2), chief engineer on the Sante Fe, states that hickory is now one of their most desirable species, because it can be seasoned with a minimum of degrade and treated adequately with preservatives.

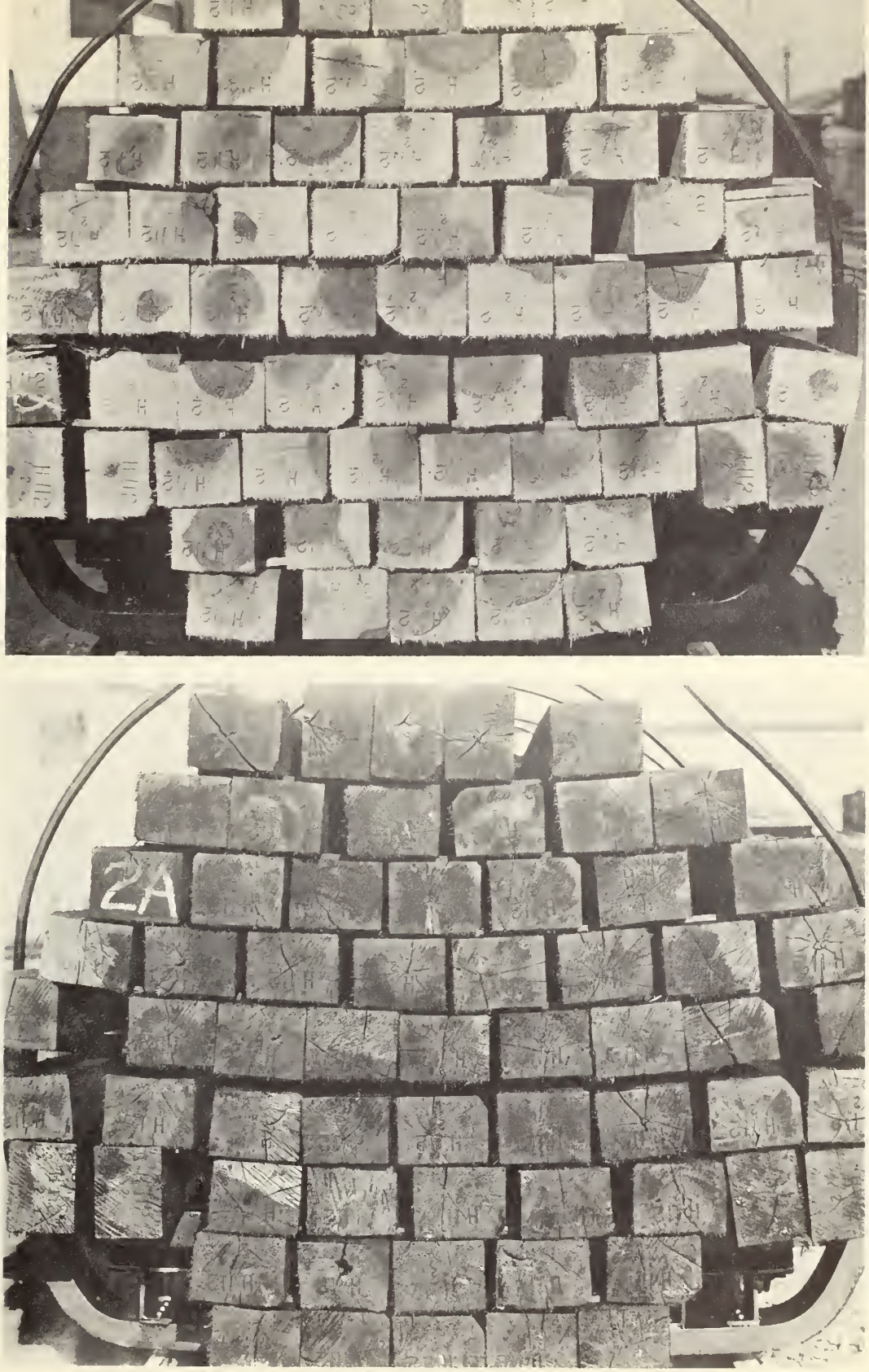

Figure 4.--End view of a tram load of hickory crossties dried by vapor-drying and then pressure treated. Above, crossties before drying. Below, crossties after drying and treating. (Photo by Santa Fe.)

Diechman[3/] made an experimental vapor-drying run on 718 green hickory crossties in Spartanburg, South Carolina. The average initial moisture content of the ties based on a sample of 60 ties was 55.2 percent. After 15 hours of vapor-drying, the ties were reduced to an average moisture content of 32.1 percent. In order to observe the influence of drying on end checking, sketches and photographs (fig. 5) were made of both ends of each tram load of ties. All checks measuring over an eighth of an inch were recorded on the sketches. Two hundred and nineteen ties showed evidence of checks before drying. After vapor-drying and treating, the checks of these 219 ties were re-measured to determine the increase in check width which resulted from drying. The results of this analysis are as follows:

Check-width increase (Inch)	Number of ties	Percent of total ties
0.1	105	48
0.2	75	34
0.3	22	10
0.4	11	5
0.5	6	3
Total	219	100

These data indicate that hickory ties containing checks can be dried by the vapor-drying process without considerable increase in check width. In this experiment only 8 percent of the ties showed an increase in check width of 0.4 inch or more.

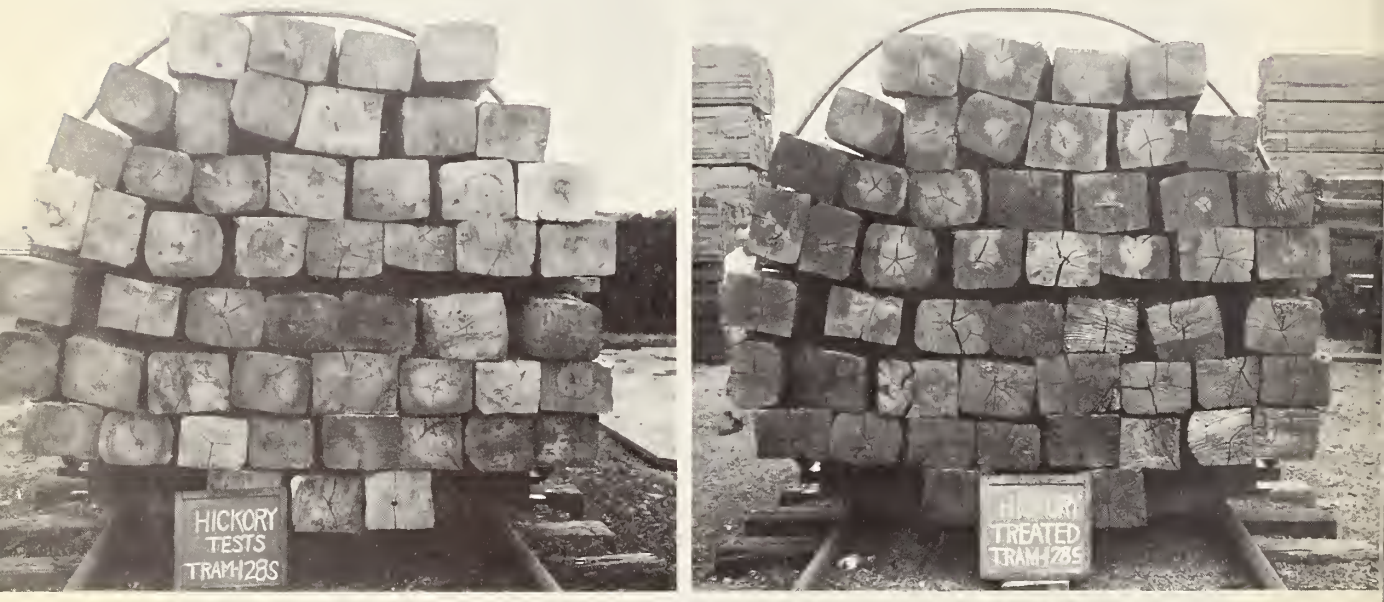

Figure 5.--End view of a sample tram load of hickory crossties, vapor-dried and treated with an 80/20 mixture of creosote and coal tar. Left, before drying. Right, after drying and treating. (Photo by Taylor-Colquitt Co.)

3/ Deichman, M. W. Vapor-drying and treatment of hickory cross ties. Unpublished report, Taylor-Colquitt Company, 5 mimeographed pages, illus. 1954.

The treating schedule used in this experiment was as follows:

Treatment	Temperature (Degrees F.)	Pressure (P. s. i.)	Vacuum (Inch Hg.)	Time (Hours)
Steam purge	--	5	--	0.42
Initial air	--	40	--	0.08
Preservative	186-192	200	--	3.75
Final vacuum	173	--	23.0	1.42
Miscellaneous operations	--	--	--	0.42
Total impregnation time				6.09

The preservative was an 80/20 mixture of creosote and coal tar. Net retention of preservative was 8.97 pounds per cubic foot. Penetration was measured on increment cores taken at midpoint of the seven-inch face and five inches from the point where cores were removed before treatment to determine sapwood depth. Figure 6 shows the increment cores extracted for sapwood determination and penetration measurements. The average sapwood depth, determined from a sample of 60 cores, was 2.0 inches. The average preservative penetration was 2.2 inches, indicating that some heartwood penetration occurred. The minimum penetration was 0.7 inch and the maximum 4.5 inches. Sixty-eight percent of the samples showed 100 percent sapwood penetration and 15 percent showed between 90 to 100 percent sapwood penetration. It is obvious from these results that hickory may be penetrated satisfactorily without incising.

After drying and treating, all the ties were classified into condition-use classes, such as satisfactory, satisfactory if doweled on one end, satisfactory if doweled on both ends. The number and percent of ties in each of these classes are tabulated below:

Condition-use class	Number of ties	Percent of total
Satisfactory	577	80
Satisfactory when doweled on one end	74	11
Satisfactory when doweled on both ends	67	9
Total acceptable	718	100

Kiln-Drying Crossties

Kiln-drying has been used as an effective means of drying lumber for over a half century. Its use, however, has been restricted to lumber and only in rare instances has it been used to dry structural timbers, poles, and crossties. Kiln-drying of structural types of wood has been avoided because of timber size and because it was thought to be impractical and rather costly (11).

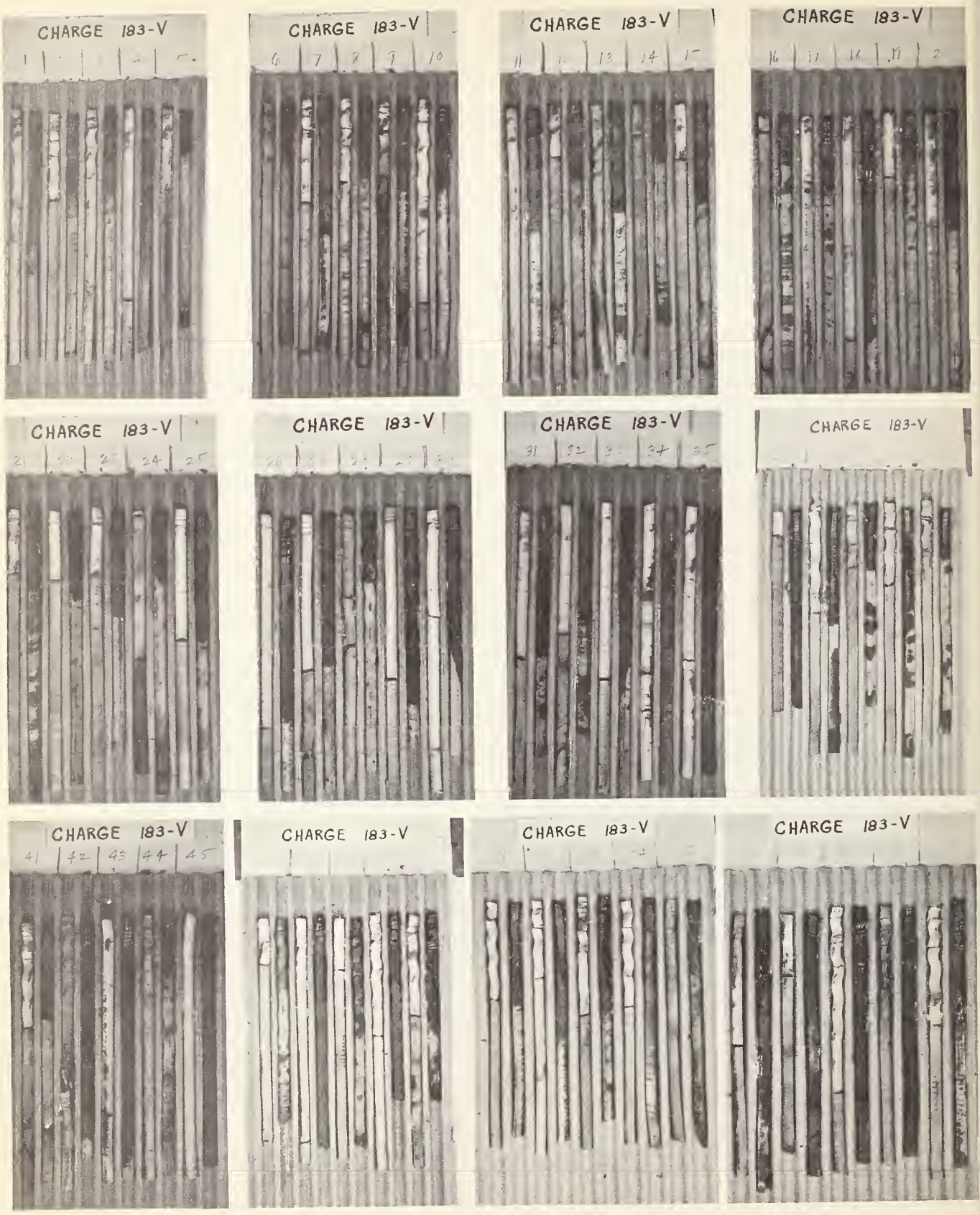

Figure 6.--Increment cores extracted from center of vapor-dried hickory ties to determine sapwood depth and depth of penetration. (Photo by Taylor-Colquitt Co.)

One of the first attempts at kiln-drying crossties was made by Huffman (10) at the University of Florida in 1955. These first experiments were made in a laboratory-type dry kiln on sweetgum (Liquidambar styraciflua L.) and tupelo (Nyssa spp.). The study showed that it was technically feasible to kiln-dry incised sweetgum and tupelo to a treatable moisture content in 3 days without objectionable seasoning defects. In view of these favorable results, the project was expanded and a second study was made in an industrial-size kiln to determine the feasibility of drying crossties on a commercial basis. This study involved the kiln-drying of 2,016 crossties in a single charge. The charge consisted of 1,875 sweetgum and tupelo, and 54 red oak (Quercus spp.), 54 hickory (Carya spp.), 22 American beech (Fagus grandifolia Ehrh.), and 11 elm (Ulmus spp.).

The objectives of this study were to obtain information on the moisture content, moisture distribution, rate of water removal, degrade when accelerated kiln-drying schedules are used, and to determine the treatability of kiln-dried ties, as well as the cost involved.

The ties were dried in a double track, cross-circulation Moore dry kiln, 135 feet long. Each tier of ties was stickered with 2 x 4-inch stickers. The kiln schedule used is shown in figure 7.

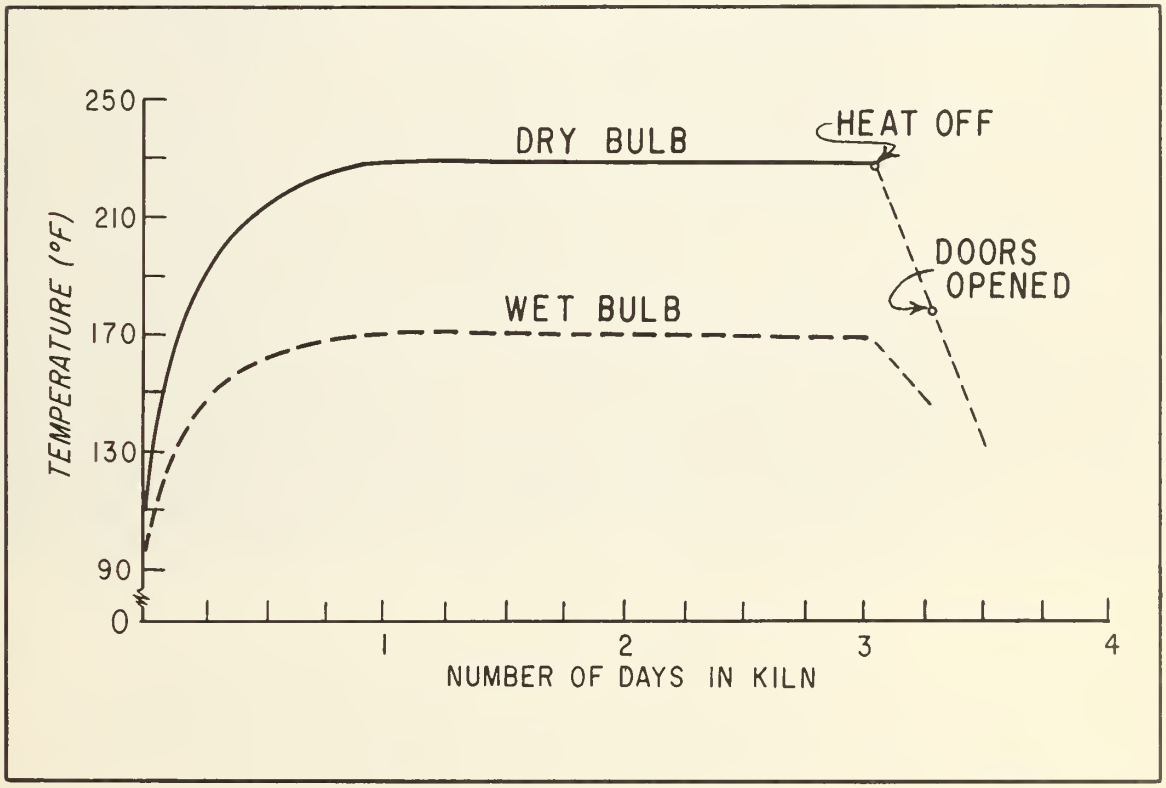

Figure 7.--Approximate kiln conditions used to dry crossties in an industrial-size dry kiln. All steam spray lines were turned off and vents were closed. Relative humidity was 30 percent and equilibrium moisture content was 2.8 percent. (Adapted from Huffman, 1958.)

The ties were segregated into heartwood volume classes, such as 0 percent heartwood, 10 percent heartwood, 30 percent heartwood, etc. There were two heartwood classes in the hickory ties used in this study, 0 percent and 30 percent. Moisture content before and after drying was determined on increment cores taken at the midpoint of 11 ties in each heartwood group. In order to determine the influence of kiln-drying on increase of check dimensions (width and length), the checks on the top face of the sample ties were measured before and after drying. The results of this analysis for hickory, as well as the other species included in the test, are shown in table 4.

Table 4.--Moisture content and check dimensions of kiln-dried crossties. 1/ (Adapted from Huffman, 1956)

Species	Heartwood volume	Moisture content		Average dimension of most objectionable checks 2/		Dimension of widest check observed 2/	
		Green	Kiln-dried	Width	Length	Width	Length
	Percent	Percent	Percent	Inch	Inches	Inch	Inches
HICKORY	0	53.5	31.7	0.26	8.4	0.50	7
HICKORY	30	53.9	46.8	0.24	12.1	0.38	20
Blackgum	0	47.5	42.5	0.08	6.5	0.13	10
Blackgum	10	87.8	49.7	0.10	6.2	0.19	10
Blackgum	30	108.4	58.1	0.13	8.2	0.19	18
Sweetgum	10	84.7	69.7	0.15	6.6	0.38	7
Sweetgum	30	79.5	77.3	0.16	7.5	0.25	6
Sweetgum	60	125.7	70.6	0.27	9.4	0.75	18
Sweetgum	90	152.0	58.6	0.20	6.3	0.38	4
Elm	100	76.2	48.3	0.22	9.4	0.50	34
American beech	20	83.3	39.2	0.25	7.9	0.50	12
American beech	50	70.3	42.6	0.20	8.7	0.38	12
Red oak group 3/	100	91.4	60.7	0.13	4.8	0.19	6
Red oak group 4/	100	82.4	61.0	0.27	7.1	0.63	9

1/ All values except those in the last two columns are based on an average of ten ties.
2/ Observations made on top face of ties.
3/ Southern red oak (Quercus rubra L.) and related species.
4/ Water oak (Quercus nigra L.) and laurel oak (Quercus laurifolia Michx.).

Seasoning checks, for the most part, were much smaller in size than those generally observed in air-seasoned ties.

None of the 2,016 kiln-dried ties were rejected because of seasoning degrade. It was necessary, however, to dowel some of the ties before they met the acceptance qualifications. The number and percent of ties of the different species that required doweling are shown in the tabulation on the following page.

Species	Total number ties	Number doweled	Percentage of species total doweled
Blackgum and sweetgum	1,875	0	0
Southern red oak and related species	11	0	0
Elm	11	1	9.1
HICKORY	54	5	9.3
American beech	22	7	31.8
Water and laurel oak	43	14	32.6
Total	2,016	27	1.3

In the case of hickory, 9.3 percent of the ties required doweling before acceptance. Figure 8 shows the condition of 10 hickory crossties after kiln-drying.

Figure 8.--Hickory crossties after 3 days of kiln-drying under high temperature schedule. (Photo by Huffman.)

In order to establish the cost of kiln-drying ties, Huffman measured the amount of steam and electricity consumed in drying the ties over the 3-day period. Total consumption of steam amounted to 210,807 pounds or 104.6 pounds per tie. Total cost of steam, based on a steam cost of $1.50 per thousand pounds, amounted to $316.21 or 15.7 cents per tie. Electrical power consumed amounted to 1,311.05 kw-hr. or 0.6503 kw-hr. per tie. The power cost, based

on a rate of 2.5 cents per kw-hr., amounted to $32.78 or 1.63 cents per tie. Total steam and power costs for 3 days of kiln-drying was 17.33 cents per tie. Huffman stated that these data provide strong arguments for the fact that it is feasible from both a technical and economical standpoint to prepare green hardwood crossties for preservative treatment by kiln-drying.

To determine the treatability of kiln-dried crossties, specific information was collected on 154 selected crossties. These consisted of 11 ties from each of the 14 heartwood volume groups listed in table 4. All of these ties were approximately seven by nine inches in cross-section and had boxed hearts. The ties were treated with an 80/20 mixture of creosote and coal tar, using the following conditions:

Initial air pressure	75 p. s. i.
Treating pressure	195 p. s. i.
Average treating temperature	202° F.
Pressure period	4.5 hours

This charge contained mostly gum ties because this species was the primary one under study. No modification of the treating schedule was made to favor the hickory, oak, and beech ties, and it was expected that these ties might receive substandard treatments. The gross absorption and net retentions of preservative, based on tank measurements, was 11.94 and 7.04 pounds per cubic foot, respectively. Preservative retentions determined by the actual before and after weights of the selected test ties are shown in table 5 by species and heartwood volume classes, together with the average penetrations.

Table 5. --Preservative retention and penetration in pressure treated kiln-dried crossties 1/
(Adapted from Huffman, 1956)

Species	Heartwood volume	Creosote retention	Creosote penetration
	Percent	Lbs./cu. ft.	Inches
Blackgum	0	7.6	1.9
Blackgum	10	7.0	1.9
Blackgum	30	6.8	1.5
Sweetgum	10	6.7	2.5
Sweetgum	30	6.7	1.3
Sweetgum	60	6.3	1.4
Sweetgum	90	6.6	1.8
Elm	100	7.2	2.4
HICKORY	0	5.9	2.6
HICKORY	30	5.0	1.9
American beech	20	5.3	1.8
American beech	50	5.1	1.6
Red oak group 2/	100	4.3	1.5
Red oak group 3/	100	4.3	0.8

1/ Values based on average of ten ties.
2/ Southern red oak and related species.
3/ Water and laurel oaks.

The hickory, beech, and red oak groups treated under this schedule did not have adequate preservative retention (4.3 to 5.9 pounds per cubic foot). In spite of these low retentions, penetration of preservative was excellent in the hickory, ranging from 1.9 to 2.6 inches. Higher retention may have resulted if the treating schedule had been adjusted for the hickory.

SERVICE LIFE

Practically all crossties used today are treated with some preservative before being installed in service. Hickory, just as all other hardwoods that are used for crossties, is relatively non-durable when untreated. Service tests show that 110 untreated hickory crossties installed by the Chicago, Burlington and Quincy Railroad in 1910 were removed because of decay after an estimated life of 5.5 years (3). This rather short service life is typical of the majority of our hardwood and softwood species that are used in contact with the ground without adequate preservative treatment. The following tabulation shows the average life of some untreated hardwood crossties.

Species	Ties in test (Number)	Average service life (Years)
Ash	116	5.1
American beech	208	5.0
Red birch	217	3.6
Chestnut	259	9.7
Cottonwood	86	2.9
White elm	191	5.3
HICKORY	110	5.5
Hard maple	122	4.7
Soft maple	125	3.6
White oak	125	11.1
Red oak	204	5.3
Pin oak	126	6.3
Poplar	126	5.3
Sweetgum	152	4.1
Sycamore	131	3.3
Tupelo	136	3.5

Hickory when seasoned and treated properly has given excellent service. Kemp (13) reported on the serviceability of 861 hickory crossties that were placed in a test track in 1922 by the Norfolk and Western Railroad. The ties used in this service test were air-seasoned from 10 to 12 months and then treated by the Bethell Process with a mixture of coal tar and creosote. Retention of the preservative ranged between 5.3 and 7.5 pounds per cubic foot. The ties were laid in two different tracks having similar characteristics of grade, alignment, speed, and tonnage. The results of an inspection in 1951 of these test tracks are shown in table 6. Table 6A contains service life data on the eastbound test track, and table 6B for the westbound test track. After 20 years of service, 241 ties or 68.9 percent of the original 350 ties laid in the eastbound track were still in service. In the westbound track, 95 ties or 18.6 percent of the original 511 were still serviceable. Using the Forest Products Laboratory Tie Renewal Curve, the average estimated service life of these hickory ties was 35 years for the eastbound track and 26 years for the westbound track. The difference in service life between these two test tracks was not determinable from the data.

The major cause for removal of ties was decay at the rail base. Although the tonnage hauled over these tracks was rather light (approximately 70 million tons), the condition of hickory as compared to red oak in the same track indicates hickory will give satisfactory service fully as long as red oak.

Table 6A. --Service life of hickory ties in Norfolk and Western Railway Test Track, Radford Division (13)

Eastbound Track--Total ties installed in 1922: 350

Year	Number of ties removed							Percent removed for all causes	
	No reason given	Decay at rail base	Decay at rail base and split	Heart decay	End decay	General decay	Split end	Period	Cumulative
1929	2	-	-	-	-	-	-	0.6	0.6
1931	-	-	-	-	-	-	-		
1932	1	-	-	-	-	-	-	0.3	0.9
1933	2	-	-	-	-	-	-	0.6	1.5
1937	-	1	2	-	-	-	-	0.9	2.4
1941	-	43	-	8	-	-	-	14.6	17.0
1943	-	-	-	-	-	-	-		
1945	1	3	-	-	-	8	1	3.7	20.7
1948	3	28	6	-	-	-	-	10.6	31.3
1950	-	-	-	-	-	-	-		
1951	-	-	-	-	-	-	-		
Totals	9	75	8	8	-	8	1		
Percent of total	2.6	21.4	2.3	2.3	-	2.3	0.3		

Total ties still in track in 1951 241
Percent of ties still in track in 1951 ..... 68.9 percent
Estimated average service life ..... 35 years

Table 6B. --Service life of hickory ties in Norfolk and Western Railway Test Track, Radford Division (13)

Westbound Track--Total ties installed in 1922: 511

Year	Number of ties removed							Percent removed for all causes	
	No reason given	Decay at rail base	Decay at rail base and split	Heart decay	End decay	General decay	Split end	Period	Cumulative
1929	1	-	1	-	-	-	-	0.4	0.4
1931	1	-	-	-	-	-	-	0.2	0.6
1932	-	-	-	-	-	-	-		
1933	4	1	-	-	-	-	-	1.0	1.6
1937	2	19	23	18	-	-	4	12.9	14.5
1941	26	186	2	27	2	-	1	47.7	62.2
1943	19	-	-	1	-	-	-	3.9	66.1
1945	17	38	-	1	-	6	-	12.1	78.2
1948	1	-	-	-	-	-	-	0.2	78.4
1950	7	-	-	-	-	-	-	1.4	79.8
1951	8	-	-	-	-	-	-	1.6	81.4
Totals	86	244	26	47	2	6	5		
Percent of total	16.8	47.7	5.1	9.2	0.4	1.2	1.0		

Total ties still in track in 1951 95
Percent of ties still in track in 1951 ..... 18.6 percent
Estimated average service life ..... 26 years

The A.R.E.A. Committee 3 on Ties made a study in 1946 at the Roanoke Materials Yard of the Norfolk and Western Railroad to determine the causes of the removal under high density traffic conditions (average 195 million tons). Five hickory ties were found in various divisions of the road and inspected. Of these 5 ties, 4 were removed because of splitting and 1 for ballast abrasion, after 24 years of service.

Results of long-term tie service tests by the Baltimore and Ohio Railroad at Backus, Pennsylvania, and Hills-Loveland, Ohio, shown in tables 7 and 8, and also those of the Chicago, Burlington and Quincy Railroad, shown in table 9, point out that hickory performs as well in service as the other species commonly used for crossties.

Table 7. --Service tests results of creosoted mixed hardwood after 43 years of testing on the Baltimore and Ohio Railroad at Backus, Pennsylvania 1/ (12)

Kind of wood	Ties placed	In test	Removed to date 2/		Average life to date
	Number	Number	Number	Percent	Years
Red oak	72	7	65	90	31.6
Black oak	260	17	243	93	32.6
Pin oak	316	17	299	95	32.7
Maple	543	143	400	74	34.4
Beech	824	98	726	88	31.6
Birch	19	4	15	79	31.4
Cherry	9	1	8	89	30.0
Gum	12	1	11	92	31.8
Chestnut	170	0	170	100	21.2
HICKORY	146	9	137	94	30.0
Total	2,371	297	2,074	87	31.6

1/ Ties originally treated with 10 pounds per cubic foot of creosote.
2/ Report is based on 1953 renewals.

Table 8. --Results of service tests after 24 years testing on Baltimore and Ohio Railroad at Hills-Loveland, Ohio 1/ (12)

Kind of wood	Retention	Ties placed	In test	Ties removed to date 2/	
	Lbs./cu.ft.	Number	Number	Number	Percent
Chestnut	8.97	400	2	398	99.50
Gum	8.97	400	389	11	2.75
HICKORY	8.48	400	352	48	12.00
Sap beech	8.97	200	190	10	5.00
Heart beech	10.47	200	186	14	7.00
White oak	5.47	600	581	19	3.20
Red oak	8.15	743	638	105	14.13

1/ Ties treated with 60/40 mixture of creosote and petroleum.
2/ Report is based on 1953 renewals.

Table 9. --Service test results on creosoted crossties after 32 years exposure in test track of Chicago, Burlington and Quincy Railroad (3)

Species	Total ties placed	Total removed in 1941	Removed on account of decay	Removed on account other causes	Estimated average life	Actual average life to date 1/
	Number	Number	Percent	Percent	Years	Years
EAST LINES						
Ash	19	19	32	68	--	16.7
Beech	321	171	17	37	34.5	27.6
Birch	75	74	72	27	--	22.9
Cottonwood	88	59	16	51	30.0	26.5
Elm	208	162	38	39	29.0	25.1
HICKORY	10	8	20	60	28.5	25.4
Hard maple	82	73	57	31	26.0	24.8
Soft maple	139	134	51	45	--	19.9
White oak	25	18	16	56	29.5	27.5
Red oak	165	123	10	65	29.5	25.8
Pin oak	189	124	8	58	31.5	26.5
Poplar	50	39	18	60	28.5	24.0
Red gum	89	73	39	43	28.0	21.4
Sycamore	75	51	42	27	31.0	25.7
Tupelo gum	99	83	32	51	27.5	22.9
WEST LINES						
Ash	15	15	20	80	--	20.7
Beech	163	83	12	39	35.0	26.9
Birch	59	49	19	64	27.5	23.2
Cottonwood	45	22	20	29	36.0	25.9
Elm	119	69	14	44	33.5	25.9
HICKORY	15	14	13	80	--	22.0
Hard maple	34	25	21	53	29.5	23.7
Soft maple	63	47	34	42	29.0	22.9
White oak	15	14	27	67	--	19.7
Red oak	120	100	14	69	27.5	23.1
Pin oak	133	100	14	61	29.0	25.8
Poplar	30	27	17	73	26.0	17.6
Red gum	48	34	29	42	30.0	20.4
Sycamore	15	4	--	27	42.0	28.3
Tupelo gum	54	40	28	46	29.5	21.7

1/ Based on 1941 inspection.

SUMMARY

Hickory has been discriminated against as a crosstie species by most of the railways in eastern United States. The reasons given for not using hickory were that it was difficult to season without serious degrade and difficult to treat properly with preservatives. The studies reported in this publication show that hickory crossties can be dried to a moisture content level between 20 and 40 percent with a minimum amount of degrade by: (1) Air-drying in 6 months to a year; (2) Controlled-Air-Seasoning in 11 days; (3) kiln-drying in 3 to 5 days; and (4) vapor-drying in 14 hours. The current seasoning practices used in drying crossties do not eliminate splitting entirely; however, many of the ties that do split during seasoning can be salvaged by doweling. Incising has also been helpful in reducing the degree of checking in seasoning. Although seasoning hickory was considered a problem in the past, it should not be considered a problem any longer in view of the seasoning results obtained in the various experiments reported here.

In considering the treatability of hickory, it is apparent from the data presented by the various investigators that difficulty is sometimes encountered. In some cases the penetration and preservative retention requirements fall short of those prescribed under A.W.P.A. and Federal Specifications. There were, however, other investigators who were able to treat hickory to meet the specifications. Incising has also been helpful in that it improved the uniformity of preservative penetration.

Although hickory may treat erratically, and in some cases not meet the necessary specifications, the ultimate criterion for judging the suitability of any species lies in its service test records. The long-time service tests have shown that hickory ties have service records equal to the other preferred hardwood crosstie species which have been treated and exposed under similar conditions.

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